**TECHNICAL MEMORANDUM**

August 6, 2001

TO: Paul Allen — STI Ref. No. 998474-2007

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SUBJECT: Recommendations for emission estimates for the Northern Baja California region of the SCOS97–NARSTO domain

## Overview

The 1997 Southern California Air Quality Study–North American Research Strategy for Tropospheric Ozone (SCOS97-NARSTO) modeling region contains a portion of Northern Baja California, which includes Tijuana, Mexicali, and Tecate. The 1990 gridded inventory includes emission estimates for northern Baja California. The portion of the study domain that is in Baja California is small (just a little over 2 percent of the whole study domain) and lies on the southern edge of the study area. This technical memorandum reports the findings of our review of a draft 1990 Northern Baja California emission inventory, our emissions estimates for 1997 for use in the current study, and future-year projection factors. Note that our efforts focused primarily on the ozone precursors (e.g., TOG and $NO_x$), but this memorandum includes all criteria pollutants from the draft 1990 Northern Baja California emission inventory. The 1990 Northern Baja California emission inventory was developed as a draft inventory for the southern-most portion of the Southern California Air Quality Study (SCAQS) domain (Systems Applications International, Inc., 1997). The inventory was developed from a combination of emission estimates obtained from the Mexican Government, emissions activity and demographic statistics from various sources, and U.S. Environmental Protection Agency (EPA) emission factors. The documentation for the 1990 inventory is entitled "Preparation of a Draft 1990 Gridded Emission Inventory for Southern California (Section 6)".

The Northern Baja California emission inventory contains estimates of TOG, $NO_x$, CO, $SO_x$, and PM for point, area, on-road mobile sources, and a category called "unknown". The 1990 Northern Baja California emission estimates were assessed using engineering judgment combined with information amassed from studies conducted in the Ciudad Juarez, Mexico border region of Texas (Haste et al., 1998) and Mexicali (Radian International, 2000). The remainder of this memorandum is divided into the following three sections:

1. Summary and review of the draft 1990 Northern Baja California emission inventory
2. Estimated 1997 emission inventory and future-year projection factors
3. Recommendations for future improvements

**Summary and Review of the Northern Baja California Emission Inventory**

Northern Baja California is a rapidly growing urban region with a strong economy and a high migration rate. San Diego and Tijuana constitute the largest urban area on the U.S./Mexico border, with considerable industrial economic activity. The maquiladora industry in Tijuana employs more than one third of the total working population. **Table 1** lists the estimated 1990 emissions for the Northern Baja California region by major source type (point, area, mobile and unknown). The Northern Baja California region contributes a small portion of the total emissions in the SCAQS modeling domain. Nevertheless, it is worthwhile to develop emission estimates that are as accurate as possible.

Table 1. Summary of the 1990 Northern Baja California emission inventory (tons/day). (Source: Systems Applications International, Inc., 1997)

| Source Category | TOG | $NO_x$ | CO | $SO_x$ | PM |
|---|---|---|---|---|---|
| Point | 1.7 | 24.2 | 15.7 | 142.9 | 20.5 |
| Area | 111.7 | 35.9 | 30.7 | 53.5 | 1.4 |
| Mobile | 101.8 | 29.4 | 580.6 | 0 | 0 |
| Unknown | 230.3 | 23.4 | 309.1 | 6.9 | 58.8 |
| Total | 445.5 | 112.9 | 936.1 | 203.3 | 80.7 |

Examination of the emission inventory documentation (Systems Applications International, Inc., 1997) shows that:

1. Point source emission estimates (which appear to include only power plant emissions) were obtained from the Mexican Government.
2. Area source emissions (which appear to be limited to only a few residential and commercial source categories) were calculated using population and employment combined with EPA emission factors.
3. Mobile source emissions (including only on-road emissions) were estimated using fuel sales and vehicle counts to estimate vehicle miles traveled (VMT) as input to MOBILE5a. The San Diego Association of Governments (SANDAG) provided vehicle counts (by vehicle type) for Tijuana, and Systems Applications International, Inc. (SAI) extrapolated these data to Mexicali and Tecate based on population.

**Figure 1** illustrates the emissions data in Table 1. As shown in Figure 1, area and mobile sources each contribute about 25 percent of TOG in the inventory, while the unknown fraction makes up the remaining 50 percent. Area, mobile, and point sources each contribute about 20 to 30 percent of total $NO_x$ emissions while the unknown component contributes about 20 percent. Mobile sources are the largest source of CO emissions, contributing about 60 percent to total CO emissions. The unknown component of the inventory is a large contributor to the total emissions, particularly for TOG.

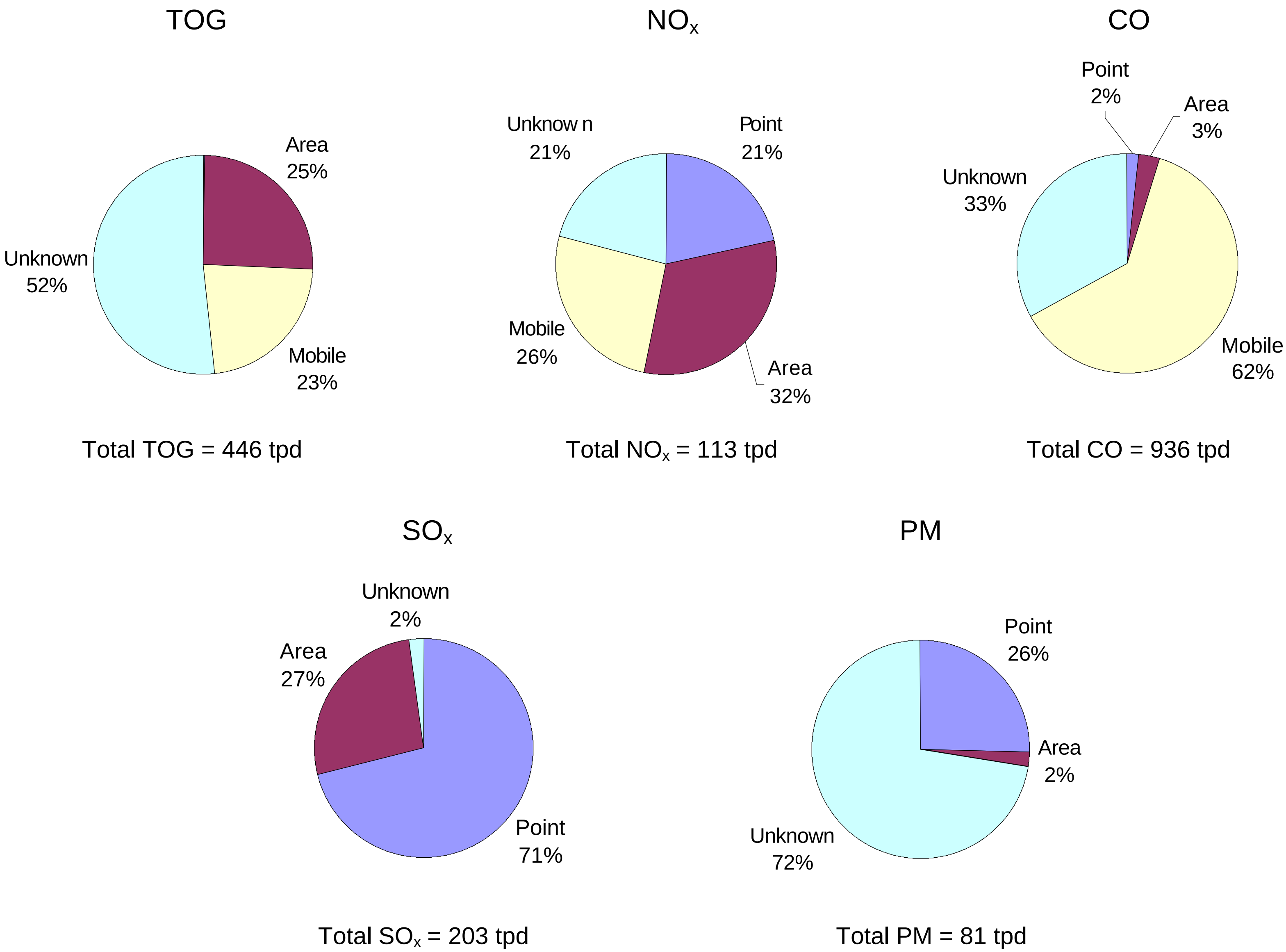


Figure 1. Source category contributions to TOG, $NO_x$, CO, $SO_x$, and PM in the 1990 Northern Baja California emission inventory. tpd = tons per day

It was not possible to perform a quantitative evaluation of the Northern Baja California emission inventory. The documentation was insufficient to support a bottom-up analysis or an assessment of emissions and emissions-related activity data used to develop the inventory. Furthermore, because of the limited source category resolution, it was impossible to discern what sources contributed to the "unknown" category emissions. We suspect that point sources such as the maquiladoras are included in the unknown category. We attempted to evaluate the magnitude of emissions in each sector of the inventory, using the activity data reported by Systems Applications International, Inc. (1997). Unfortunately, the activity data presented in the emission inventory documentation contained numerical errors (see Number of Vehicles, pp. 6-11 in Systems Applications International, Inc., 1997), preventing any independent recalculations.

Therefore, we conducted a review based on our experience with the emission inventory for the El Paso, TX/Ciudad Juarez, Mexico region (which has similar demographic characteristics) and emissions for Mexicali reported by Radian International (2000). For comparison purposes and for potential use for 1997 emission estimates, the area and mobile source inventories for the area of Northern Baja California within the SCOS97 domain were re-estimated using per capita scaling factors and data from Ciudad Juarez and Mexicali, Mexico. The point and unknown components of the 1990 inventory could not be examined because operating schedules and activity data for point sources are not necessarily similar between cities and no information about the unknown category is available. Demographic scaling factors are not applicable to point sources because there is little correlation between point source activity and population.

To develop appropriate demographic scaling factors to be used in assessing Northern Baja California's 1990 emissions and estimating 1997 emissions, we obtained data on vehicle counts and population for Northern Baja California. For comparison, **Table 2** lists the population and vehicle data used by SAI to calculate area and mobile source emissions for the 1990 inventory.

Table 2. Population and vehicle count data used to calculate area and mobile source emissions for the 1990 Northern Baja California emission inventory. (Source: Systems Applications International, Inc., 1997)

| Region | Population | Cars | Trucks and Buses | Population/Car |
|---|---|---|---|---|
| Tijuana/Rosarita (1990) | 747,381 | 170,149 | 39,836 | 4.4 |
| Mexicali/Tecati (1990) | 653,495 | 117,626 | 352 | 5.6 |
| Mexico Domain (1990) | 1,400,876 | 287,775 | 40,188 | 4.9 |

To estimate population data for 1997, we used growth figures reported by SANDAG. According to SANDAG, the current population of Tijuana is approximately 1.2 million people with an average annual population growth rate of 5.5 percent (SANDAG, 2000). This high growth rate is attributable to the migration of people into Tijuana. In order to calculate population figures for 1997, population data for 2000 were back-cast by applying a 5.5 percent annual decrease over three years. Population figures for the Mexicali/Tecate region were projected from the 1990 figures (see Table 2) by assuming an annual growth rate of 2 percent (see Radian International, 2000). The number of cars and trucks for 1997 were calculated from scaling factors based on the 1990 data reported by Systems Applications International, Inc. (1997). SAI estimated per capita car ownership in 1990 to be 0.23 (about one car for every five people). A similar calculation for Mexicali/Tecate resulted in an estimate of approximately one car for every six people. These per capita vehicle ownership rates were used to scale the number of vehicles in 1997 from population estimates. The resulting counts for population and for vehicles are shown in **Table 3**.

Table 3. Population and vehicle count data for the 1997 Northern Baja California emission inventory.

| Region | Population | Cars | Trucks and Buses | Population/Car |
|---|---|---|---|---|
| Tijuana/Rosarita (1997) | 1,002,000 | 228,116 | 53,407 | 4.4 |
| Mexicali/Tecate (1997) | 744,984 | 134,094 | 401 | 5.6 |
| Northern Baja California Total (1997) | 1,746,984 | 362,209 | 53,809 | 4.8 |

**Table 4** lists VOC, $NO_x$, and CO emissions for Ciudad Juarez, compiled as part of the Paso del Norte Ozone Study sponsored by the EPA (Haste et al., 1998). The emission inventory for Ciudad Juarez does not include non-road mobile source emissions because they were not available at the time of the inventory compilation. The population of Ciudad Juarez in 1996 was 1,065,200 and there were approximately 351,633 light-duty vehicles and 15,066 heavy-duty diesel vehicles. These figures equate to per capita vehicle ownership rates of approximately 0.33, or one vehicle for every three people. Mobile source emission estimates for Ciudad Juarez were obtained from the Mexican government and were developed using a special adaptation of the MOBILE5 model called MOBILE5-Juarez. The MOBILE5-Juarez model uses emission factors that are based on the findings of a series of remote sensing studies performed in the Ciudad Juarez border region in 1996 (Walsh and Gertler, 1997).

Table 4. Summary of the 1996 Ciudad Juarez emission inventory (tons/day). (Source: Haste et al., 1998)

| Source Category | VOC | $NO_x$ | CO |
|---|---|---|---|
| Point | 5 | 43 | 12 |
| Area | 46 | 3 | 18 |
| Mobile | 157 | 69 | 1324 |
| Total | 208 | 115 | 1354 |

**Table 5** lists VOC, $NO_x$, and CO emissions for 1996 in Mexicali (Radian International, 2000). The population of the Mexicali region in 1996 was estimated as 717,000 and there were approximately 241,000 vehicles. These figures equate to per capita vehicle ownership rates of approximately 0.33, or one vehicle for every three people (identical to Ciudad Juarez).

Table 5. Summary of the 1996 Mexicali emission inventory (tons/day). (Source: Radian International, 2000)

| Source Category | VOC | $NO_x$ | CO | $SO_x$ | $PM_{10}$ |
|---|---|---|---|---|---|
| Point | 4 | 4 | 13 | 8 | 5 |
| Area | 42 | 2 | 52 | 0 | 170 |
| Mobile | 85 | 41 | 665 | 3 | 1 |
| Total | 131 | 47 | 730 | 11 | 176 |

Per capita emission rates by source type and pollutant for Mexicali and/or Ciudad Juarez can easily be computed using each city's population and emissions totals, illustrated below.

Example Scaling Factor Calculation

$$SF = E_{(\text{source category})} / P \text{ (or V for mobile sources)} \qquad \textbf{(1)}$$

where:
- SF = scaling factor
- E = emissions for specific source category
- P = population
- V = number of vehicles (if calculating mobile source emissions)

To calculate the per capita scaling factor for area source VOC in Ciudad Juarez:

$$SF = E_{(\text{area source VOC})} / P \qquad \textbf{(2)}$$

$$SF = 46 \text{ (tons/day)} / 1065200$$

$$SF = 0.0000432 \text{ (tons/person/day)}$$

Using the approach above, scaling factors were computed from the data for both Mexicali and Ciudad Juarez as shown in **Table 6**. While there are some differences between the cities, the resulting scaling factors are remarkably similar, with the best agreements for the ozone precursors (VOC and $NO_x$) and poorer agreement for CO. Although the use of scaling factor calculations are simplistic, they provide a reasonable method to scale emission estimates that are highly uncertain and of unknown quality. This methodology is not a substitute for bottom-up emission inventory calculations. Because the scaling factors are similar and since data for $SO_x$ and PM are available for Mexicali and not Juarez, we used the scaling factors for all pollutants for Mexicali to estimate 1997 emissions in the Northern Baja California region.

Table 6. Summary of per capita scaling factors computed from data in Mexicali and Juarez. Scaling factors are reported as tons/1000 people (or 1000 vehicles for mobile).

| Source Category | VOC | | $NO_x$ | | CO | |
|---|---|---|---|---|---|---|
| | Juarez | Mexicali | Juarez | Mexicali | Juarez | Mexicali |
| Point | 0.005 | 0.006 | 0.04 | 0.006 | 0.011 | 0.018 |
| Area | 0.043 | 0.058 | 0.0028 | 0.0028 | 0.017 | 0.072 |
| Mobile | 0.44 | 0.35 | 0.197 | 0.17 | 3.77 | 2.75 |

The area and mobile source components of the Northern Baja California emission inventory were estimated for 1997 using the population and vehicle data listed in Table 3 and the per capita emissions scaling factors derived from the 1996 Mexicali emission inventory (shown in Table 6). An example calculation is illustrated below.

<u>Example Emissions Calculation</u>

$$E_{(\text{source category})} = P \text{ (or V)} \times SF \tag{3}$$

To calculate the VOC emissions for area sources in Northern Baja California:

$$E_{(\text{area source VOC})} = 1746984 \times 0.000058$$

$$E_{(\text{area source VOC})} = 101 \text{ (tons/day)}$$

Using these procedures, an estimated 1997 Northern Baja California emission inventory can be computed. **Table 7 and Figure 2** show a summary of the 1997 Northern Baja California estimated emission inventory.

Table 7. Summary of the 1997 estimated Northern Baja California emission inventory (tons/day).

| Source Category | TOG | $NO_x$ | CO | $SO_x$ | PM |
|---|---|---|---|---|---|
| Point | 10 | 10 | 31 | 19 | 12 |
| Area | 101 | 5 | 126 | 0 | 414 |
| Mobile | 127 | 62 | 996 | 5 | 2 |
| Total | 238 | 77 | 1153 | 24 | 428 |

In order to use the estimated 1997 Northern Baja California emission inventory in place of the existing draft 1990 gridded inventory, an additional processing step is required because of the unknown category in the draft 1990 inventory. Specifically, the sum of point and area from the 1997 inventory must be used to scale the sum of the point, area, and unknown source categories in the 1990 inventory; the difference between 1997 mobile and 1990 mobile sources can be used to scale the 1990 mobile emissions. **Table 8** provides the scaling factors for this approach.

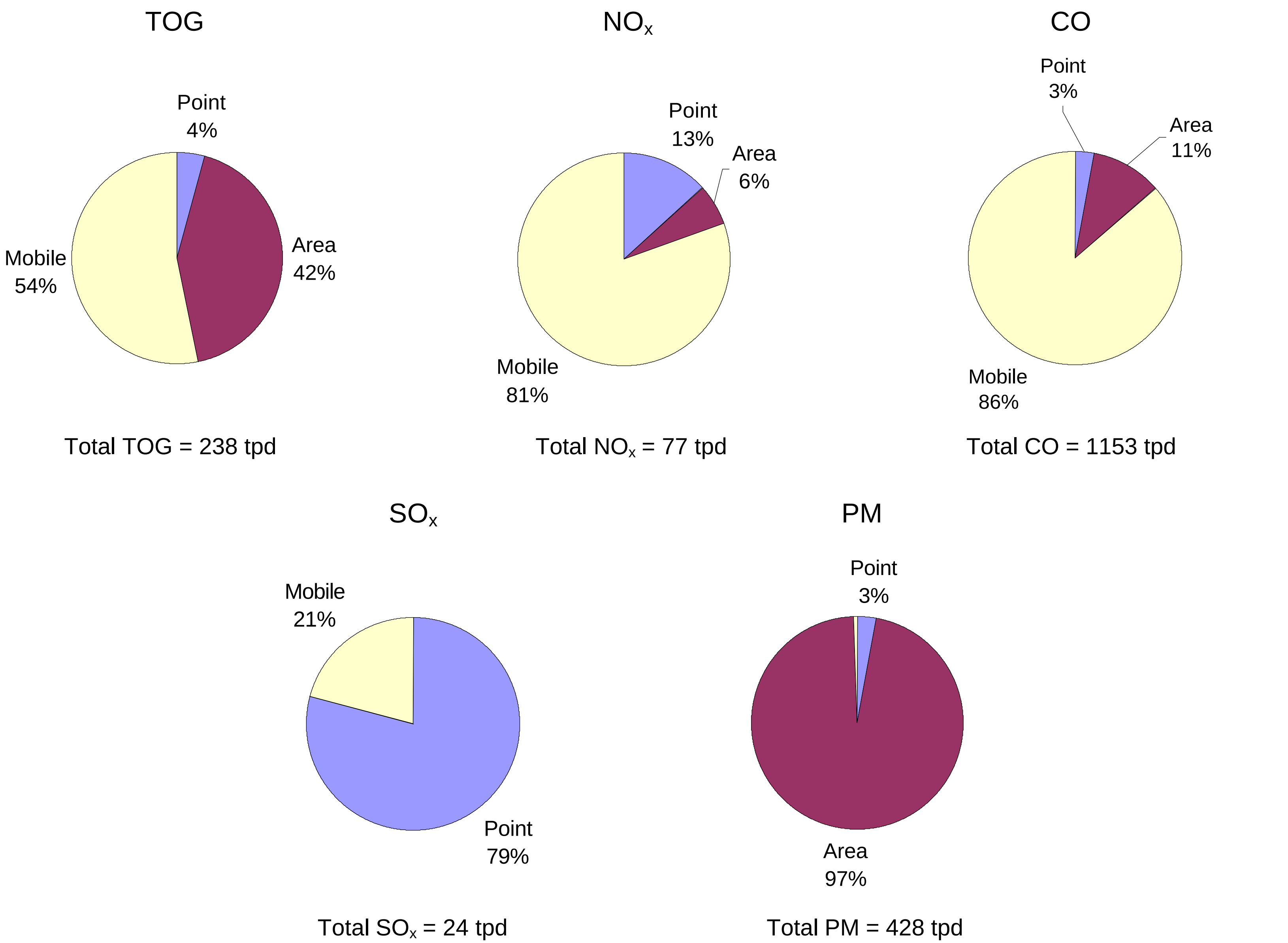


Figure 2. Source category contributions to TOG, $NO_x$, CO, $SO_x$, and PM in the 1997 estimated Northern Baja California emission inventory. tpd = tons per day

Table 8. Scaling factors to adjust the 1990 Northern Baja California emission inventory sum of area, point, and unknown source categories and mobile sources to simulate 1997 emissions.

| Source Category | TOG | $NO_x$ | CO | $SO_x$ | PM |
|---|---|---|---|---|---|
| Sum of area, point, and unknown | 0.32 | 0.17 | 0.44 | 0.09 | 5.30 |
| Mobile | 1.25 | 2.11 | 1.72 | 1.00 | 1.00 |

Future-year projection factors for 2005, 2010, and 2020 for Northern Baja California can be computed from population forecasts based on SANDAG's estimate of 5.5 percent annual population growth for Tijuana. In an economic report for Tijuana, point sources were shown to have an annual increase in GDP of about 6 percent. In addition, the Radian International report on emissions in Mexicali provides growth factors for point, area, and mobile sources from 1996 to 2005 (Radian International, 2000). In that report, it was determined that point sources would remain about the same, area source emissions would increase by about 2 percent per year (similar to population growth in the area), and mobile source emissions would decrease by about 1.6 percent per year (due to fleet turnover effects more than offsetting increased vehicle use).

Given the large uncertainty in the emission estimates for 1997, we recommend that simple projection factors be applied for point, area, and mobile emissions for the entire Northern Baja California region. However, since not all cities in Northern Baja California are growing at the high rate of Tijuana, we recommend that a growth rate of 4 percent (the population-weighted average growth rate in Northern Baja California—double that of most U.S. cities) be used for future-year forecasts for area sources and 6 percent annual growth rate for point sources. Estimating future-year mobile sources is more problematic. We might assume that the decrease in emissions from mobile sources in Mexicali (as reported by Radian International, 2000) is due to improved fleet emissions more than offsetting a growth in population of about 2 percent per year. But since we are assuming a higher growth rate for the entire Northern Baja California region, a decrease in mobile source emissions as in Mexicali is not likely. Therefore, we recommend that mobile sources not be decreased nor increased, but held constant, assuming that fleet turnover benefits are offset equally by increased vehicle use. The resulting scaling factors are shown in **Table 9**.

Table 9. Future-year emissions scaling factors (using 1997 as a base year).

| Year | Scaling Factor (percent) | | |
|---|---|---|---|
| | Point | Area + Unknown | Mobile |
| 2005 | +61% | +38% | 1.0 |
| 2010 | +118% | +68% | 1.0 |
| 2020 | +297% | +151% | 1.0 |

**Conclusions and Recommendations**

In order to adjust the 1990 Northern Baja California emission inventory at the grid-cell level, the emissions for each category in each grid cell should be increased by the percentage indicated in Table 9. In addition to scaling the emission estimates, appropriate diurnal profiles should be applied to each of the major source categories in the inventory. The 1990 gridded inventory is resolved at the diurnal level, however, the emissions were equally distributed over 24 hours. The diurnal distribution of emissions is an important factor in ozone formation, therefore, any emission inventory that is going to be used for photochemical modeling should be resolved on an hourly basis using diurnal profiles that are representative of emissions activity. Most large point sources are manufacturing facilities and/or power plants that tend to operate continuously. A temporal profile that has equal hourly distribution over 24 hours would be the most representative for point sources. Typically, area sources include commercial and retail facilities that tend to have 9 a.m. to 5 p.m. operating schedules, or schedules that reflect daily human activity patterns. Mobile sources tend to follow very different diurnal profiles on weekdays versus weekends. A typical weekday mobile source profile would follow a bimodal distribution with two peaks representing morning and evening commute traffic. Weekend traffic patterns tend to increase gradually throughout the day and peak in the early afternoon. **Figure 3** provides a graphical display of example representative diurnal profiles for point, area, and on-road mobile sources.

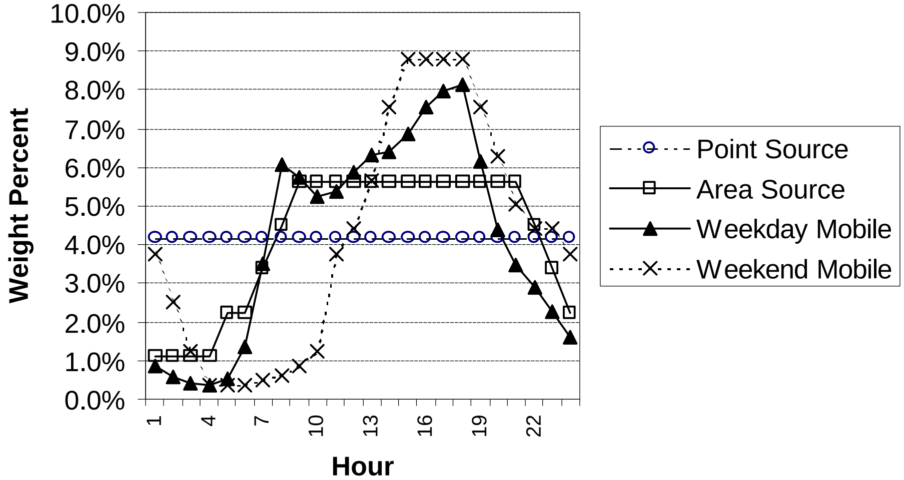


Figure 3. Representative diurnal profiles for point, area, and on-road mobile sources.

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